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SUBMINIATURE TELEMETRY TESTS USING DIRECT FIRE PROJECTILES

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U.S. ARMY LABORATORY COMMAND

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ABERDEEN PROVING GROUND, MARYLAND

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13. ABSTRACT (Maximum 200 words)

An eight round program was fired at the Transonic Range Facility, Aberdeen Proving Ground, MD, during November 1989 to determine the survivability of subminiature transmitter packages in the tracer wells of 120mm, M865, TPCSDS-T and 105mm, M724, TPDS-T projectiles and the ability to measure spin rates. The telemetry packages survived the launch environment of the M865 and transmitted spin data. The M724 appeared to generate too high of a spin environment for the battery system. The successful demonstration of this telemetry system leads to the inclusion of a subcarrier oscillator and a transducer to measure parameters other than spin.

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Mr. Alan Schmuecker, of the Motorola Corporation, provided test support, data acquisition and assembly of the projectile packages.

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I. Introduction

There is a need to measure projectile spin rate continuously and throughout the entire trajectory of direct fire munitions such as long rod kinetic energy (KE) and high explosive anti-tank (HEAT) rounds. At present, spin rate is measured with yaw cards that track the rotational position of the projectile fins. The quality of the spin rate measurement is in direct proportion to the number and location of the yaw cards. Yaw card set up is laborious and does not provide a continuous measurement of spin rate over the duration of the projectile flight. Several attempts have been made to track the projectile with Doppler radars and process the return signal to obtain spin rate. These methods have not worked uniformly, and typically the radar data are not available near the gun muzzle.

This report describes tests of subminiature transmitters designed to determine survivability of the transmitters and to measure projectile spin rate. These transmitters, manufactured by the Motorola Corporation, were designed to fit into the tracer well of the M865 flare-stabilized projectiles and the M724 spin-stabilized projectiles.

II. Background

The in-flight measurement of projectile spin, yaw and other parameters for a variety of artillery projectiles has been routinely accomplished at the Ballistic Research Laboratory (BRL) for many years using standard telemetry techniques. For the most part, the major components of the telemeter have been packaged inside the artillery projectile where the size of the telemetry components was not a concern. The antennae for these transmitters were usually contained in the nose-fuze portion of the projectile. Sometimes, the exterior of the artillery projectile body was modified to accept an antenna. In some cases, this required a sizeable amount of space and modification.

High L/D (Length over Diameter) direct fire projectiles are generally long and narrow; therefore, they have little space available to house the conventional antenna and the electronics needed for the transmitter, power source and other components. Also, a minimal amount of modification to the projectile is permitted. Because of these restrictions, standard telemetry components and the techniques employed with artillery shell can not be used with direct fire projectiles. Instead, subminiature telemetry components are required, including transmitters that operate at very high frequency to accommodate a small, efficient antenna.

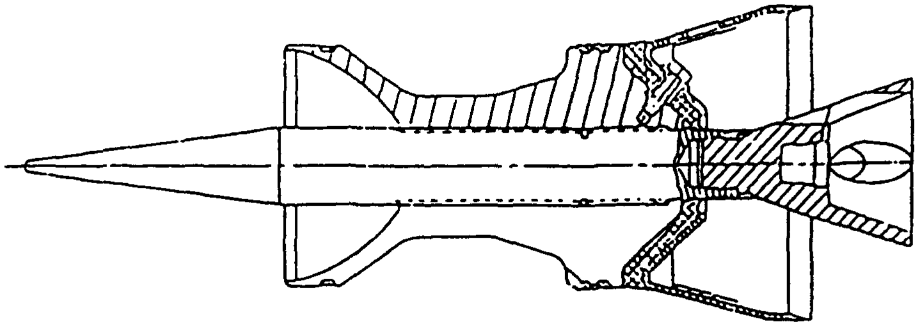


FIGURE 1. Schematic of a High L/D Direct Fire Projectile

III. Subminiature C-Band Transmitter

A schematic of a high L/D direct fire projectile is shown in Figure 1. The telemetry package, which included the antenna, the transmitter, an integral power supply and a protective plate for the antenna was located in the tracer well at the rear of the projectile.

The transmitter was designed to operate at 5.6 GHz and withstand up to 100,000 psi pressure and a linear acceleration up to 55,000 Gs.

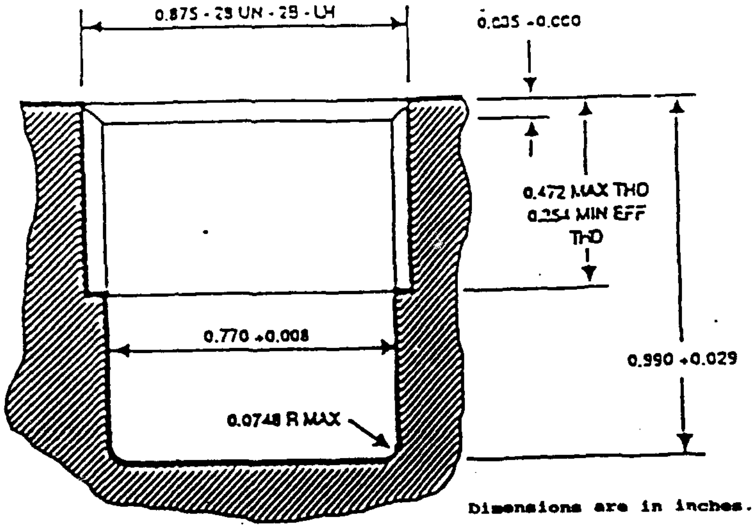


FIGURE 2. Dimensions of the M13 Tracer Well.

The antenna was a printed circuit patch of about 3mm x 2mm, plated onto an alumina oxide substrate. It was linearly polarized and had a rearward directed radiation pattern. The polarization of the antenna was used to determine the spin rate of the projectile, since the signal strength received on the ground oscillated in response to the rotating transmitter antenna pattern. A fiberglass radome protected the antenna from propellant gas during launch. The entire unit was sized to fit into the M13 tracer well cavity, shown in Figure 2.

The subminiature transmitter package was pressure and temperature tested by mounting the unit in an adaptor that was attached to the primer located inside a 120mm cartridge casing. This caused the transmitter to be exposed to the maximum pressure available from the associated charge. The test was conducted in September 1989. The two tested units survived a peak pressure of 60,000 psi and the associated high temperatures.

IV. Test Programs

Eight of the subminiature transmitters were test fired at the Transonic Range Facility of the Ballistic Research Laboratory, Aberdeen Proving Ground, Maryland in November 1989. The main objective of the test was to demonstrate survivability of the units at two launch conditions. A second objective was to demonstrate the ability to determine spin rate by monitoring the amplitude modulation of the received signal strength.

1. Ground Instrumentation

The telemetry ground receiving equipment for the test was supplied and operated by the Motorola Corporation. Their receiver was equipped with a sweep circuit that searched a broad range of frequencies. This was required because the transmitter on the projectile was a simple design and the frequency could shift significantly upon launch. Once the sweep circuit matched the transmitted frequency, a tracking circuit "locked" on to it and followed any frequency changes that occurred. An analog instrumentation tape recorder was used to record the sweep circuit output voltage and the output strength received from the transmitter.

A Doppler radar was used to provide a radial velocity versus time history. The radar data and launch time-zero indication signals were recorded. A digital signal analyzer was used to monitor the strength of the signal received from the transmitter to give a real-time indication of the projectile spin rate and transmitter performance.

2. Firing Program

The test consisted of firing eight training rounds: five M865 TPCSDS-T and three M724 TPDS-T projectiles. The 120mm M865 is a saboted projectile that is fired from the M256 smooth bore cannon with spin rates as high as 350 Hz due to canted holes in the flare.

The 105mm M724 provides a much harsher environment; it is fired from a rifled bore (M68 series cannon) and exits with a spin rate of approximately 800 Hz.

Five M865 rounds were fired, one at 10 degrees quadrant elevation and four at 15 degrees quadrant elevation. Three M724 rounds were fired, all at 10 degrees quadrant elevation. The last M724 was fired with a reduced charge in order to decrease the initial spin rate. The higher elevations (15 degrees) were chosen to prolong the flight time of the projectile and aid in receiving and processing the data. The quadrant elevations chosen were higher than typical tank gun firings.

V. Results

The spin rate measurements are summarized in Table 1. The spin rates were obtained by measuring the frequency of the oscillations in the strength of the signal received from the transmitter. The muzzle velocities were obtained from Doppler radar.

Table 1. November 1989 Flight Test Results

ROUND No.	ELEVATION (deg)	MUZZLE VELOCITY (m/s)	LENGTH of DATA (secs)	MAX SPIN (Hz)
M865				
1	10	1678	6	324
2	15	1685	6	332
3	15	1677	6	324
4	15	1674	6	350
5	15	n/a	6	330
M724				
6	10	1531	0	n/a
7	10	1526	0	n/a
8	10	1230 *	0	n/a

* Downloaded charge to five pounds.
n/a Not available

1. M724 Results

Table 1 shows that no measurements of the spin rate were obtained from the M724 firings. This is because no transmissions were received. It is not known whether the telemetry units failed outright or whether there was a major shift in center frequency. One possible explanation stems from the off axis position of the battery in the package. It is possible that the combination of linear and radial acceleration, due to the high spin rate, caused a failure in the power supply.

2. M865 Results

Signals were received from the transmitters on the M865 rounds for about 6 seconds. Spin rates were obtained for the same amount of time for all five rounds. The sampled projectile spin rate began at approximately 200 Hz and increased to 350 Hz for all five rounds.

3. Telemetry Data Plots

Figures 3 and 4 are plots of sweep circuit output voltage versus time from Round 1. In Figure 3, receiver lock, signifying acquisition of the transmitter frequency, occurred within 3 milliseconds of launch. (Launch time-zero was determined from a muzzle flash detector.) Figure 4 shows 1.25 seconds of flight. The receiver lock is shown, as well as loss-of-lock at approximately 0.8 seconds. None-the-less, the receiver tracked the signal beyond one second because the frequency of the transmitter was not varying significantly.

Figures 5-7 show different formats for the spin rate analysis. The spin rates were obtained by two separate methods: spectrum analysis and manually counting cycles. Spectrum analysis could be used to process most of the data, but it required a time delay to assure proper anti-aliasing and smoothing. For the present set of tests, the required time delay was approximately 250 milliseconds. Spin rates were obtained from 0-200 milliseconds by measuring the period of the amplitude modulation of the transmitter signal. Figures 5 and 6 display spin rates obtained from the manual method (symbols) and from spectral analysis (solid line). Figure 7 shows the spin rates versus time for all five M865 rounds. The acquisition time for all rounds was between 3-5 milliseconds and all rounds transmitted for about 6 seconds. Periodicity measurements of spin rate at early times are not shown for clarity.

M865 projectiles have been fired through the Transonic Range facility and spin rate has been determined for the initial few milliseconds of flight. Figure 8 shows Transonic Range data extrapolated for the duration of a flight and compared to the data received during the test. The spin rate has been made dimensionless with projectile diameter and muzzle velocity. The difference is due to imperfections in the extrapolation algorithm.

VI. Summary

The telemetry units in the M724 rounds did not transmit. Most likely this was due to the very high spin rates. The telemetry units in the M865 TPCSDS-T projectiles successfully measured spin from 3 to 6000 milliseconds. The maximum measured spin of the M865 projectile was 350Hz. The successful demonstration of this telemetry system leads to the inclusion of a subcarrier oscillator and a transducer to measure parameters other than spin. For example, a continuous measurement of yaw would be preferable to yaw card measurements for direct fire munitions.

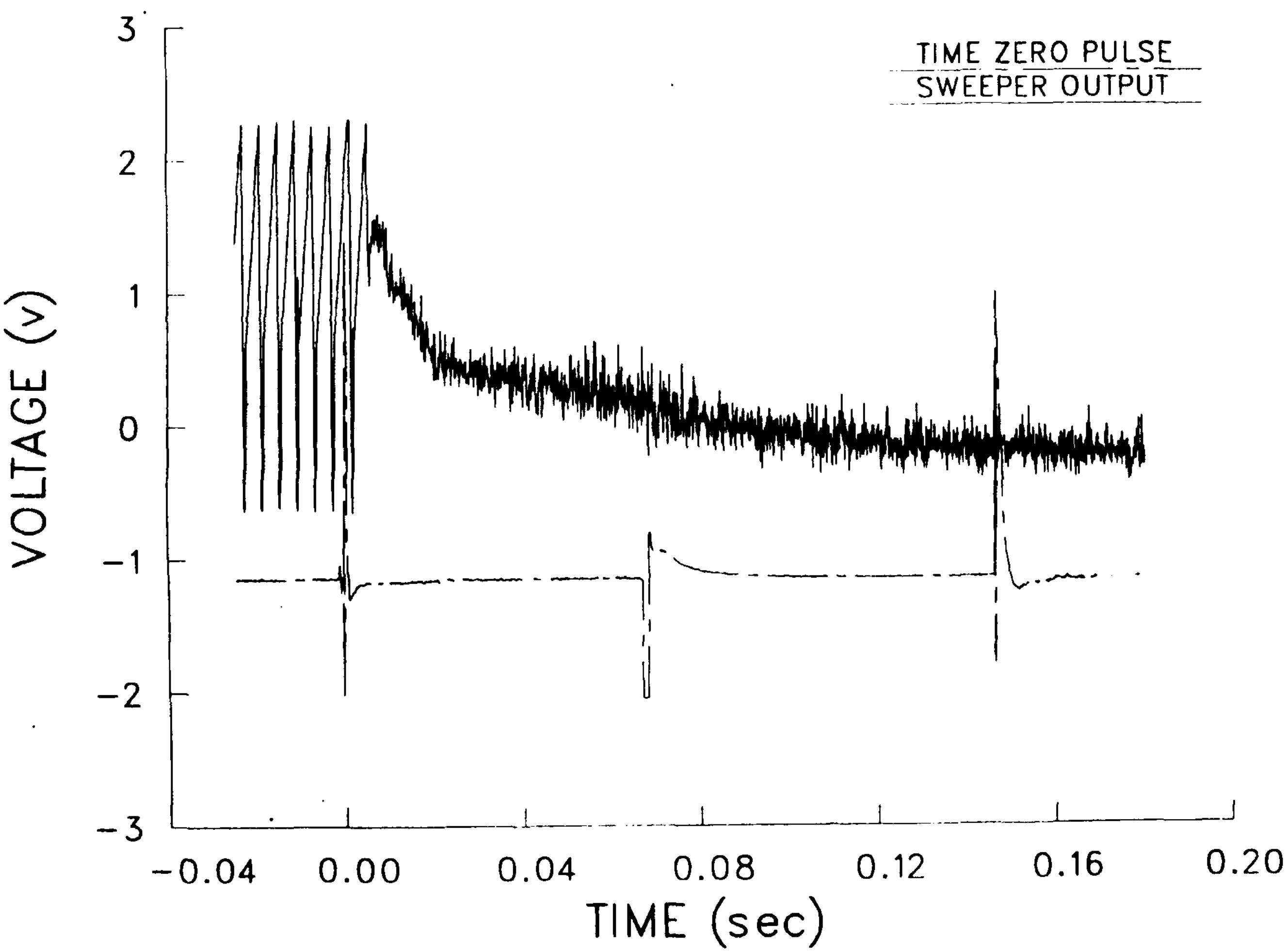


FIGURE 3. Time Zero Pulse and Sweep Signal for Round 1, First 0.20 seconds.

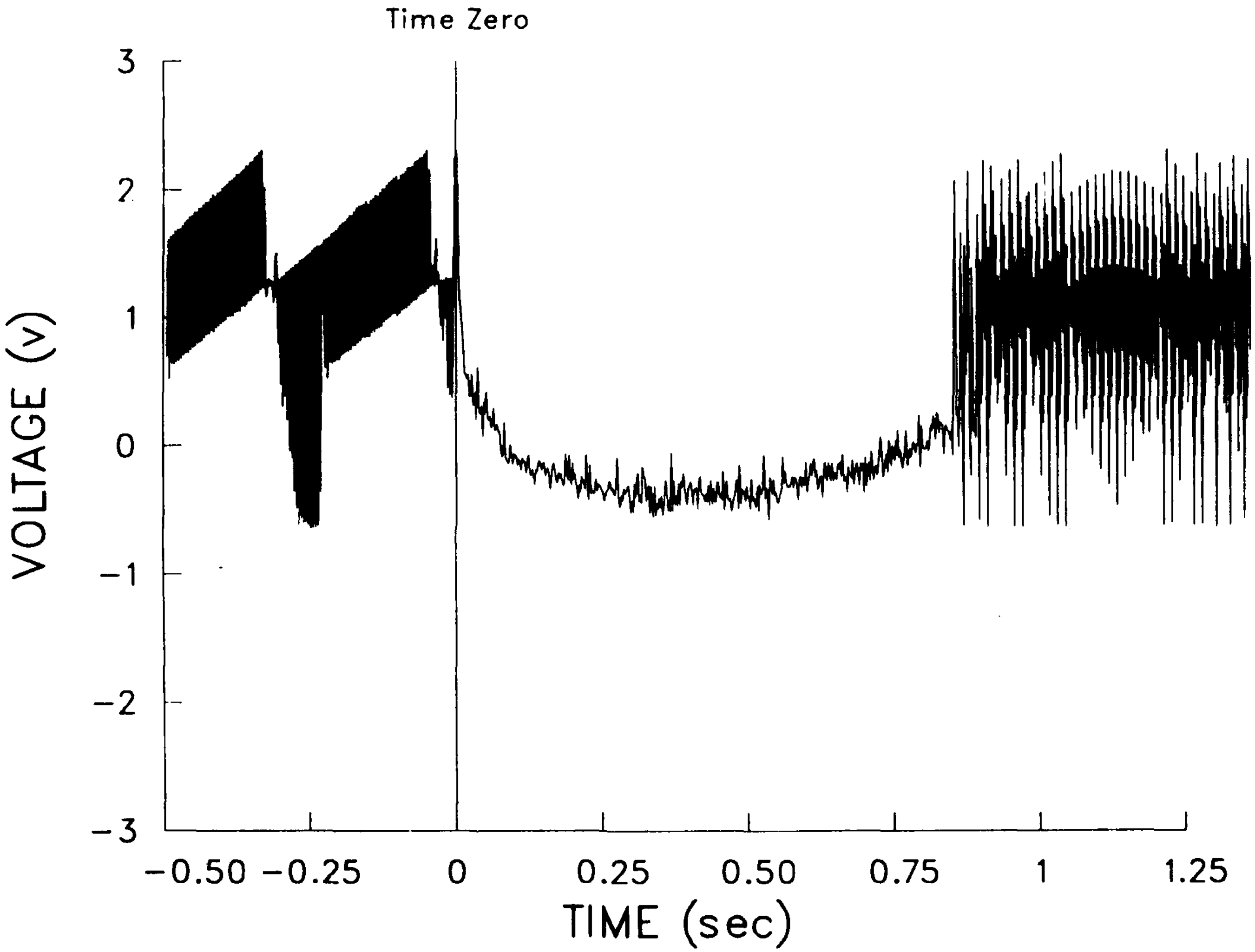


FIGURE 4. Sweep Signal for Round 1 to 1.25 seconds.

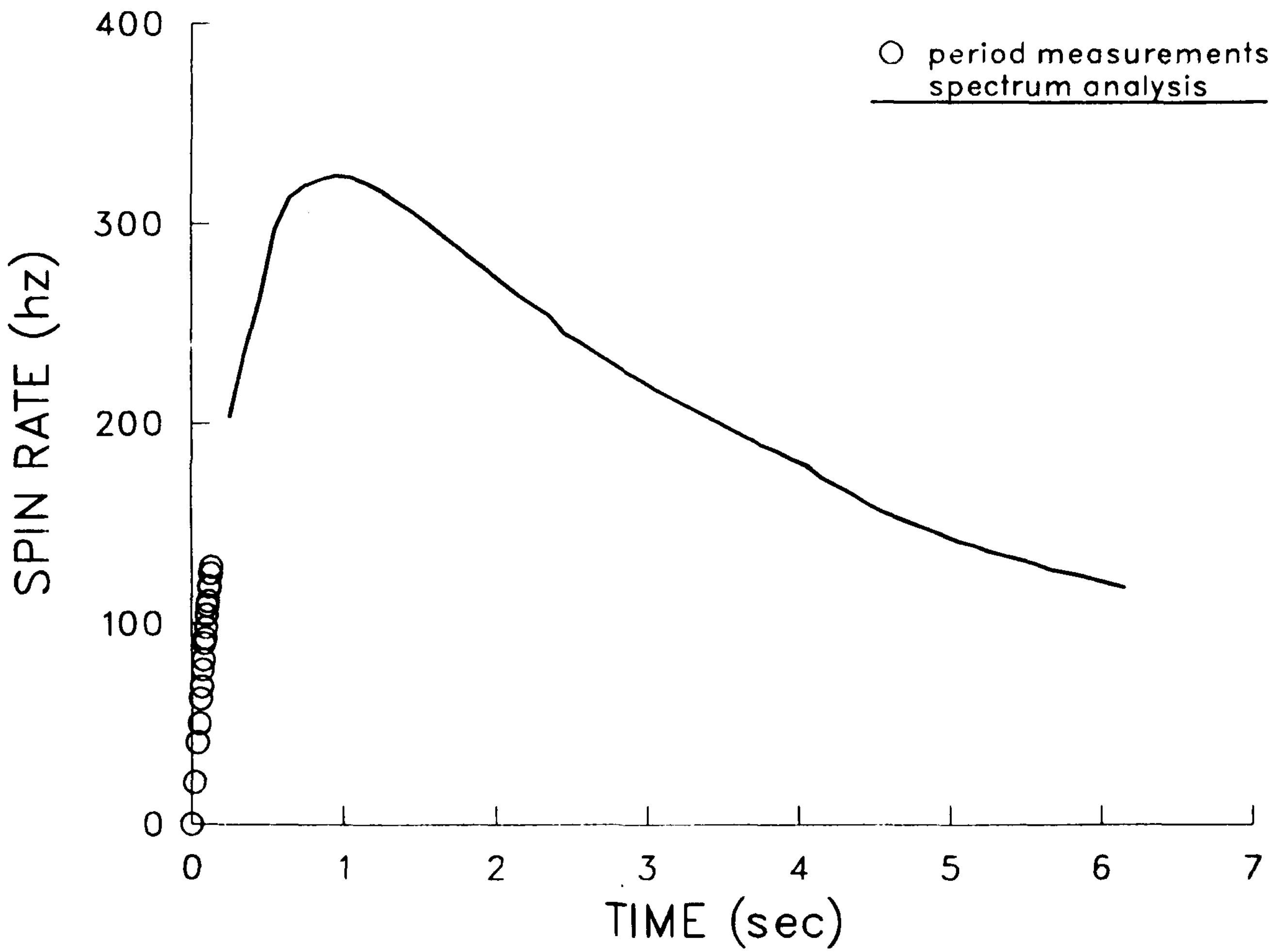


FIGURE 5. Spin Rate Measurements for Round 1.

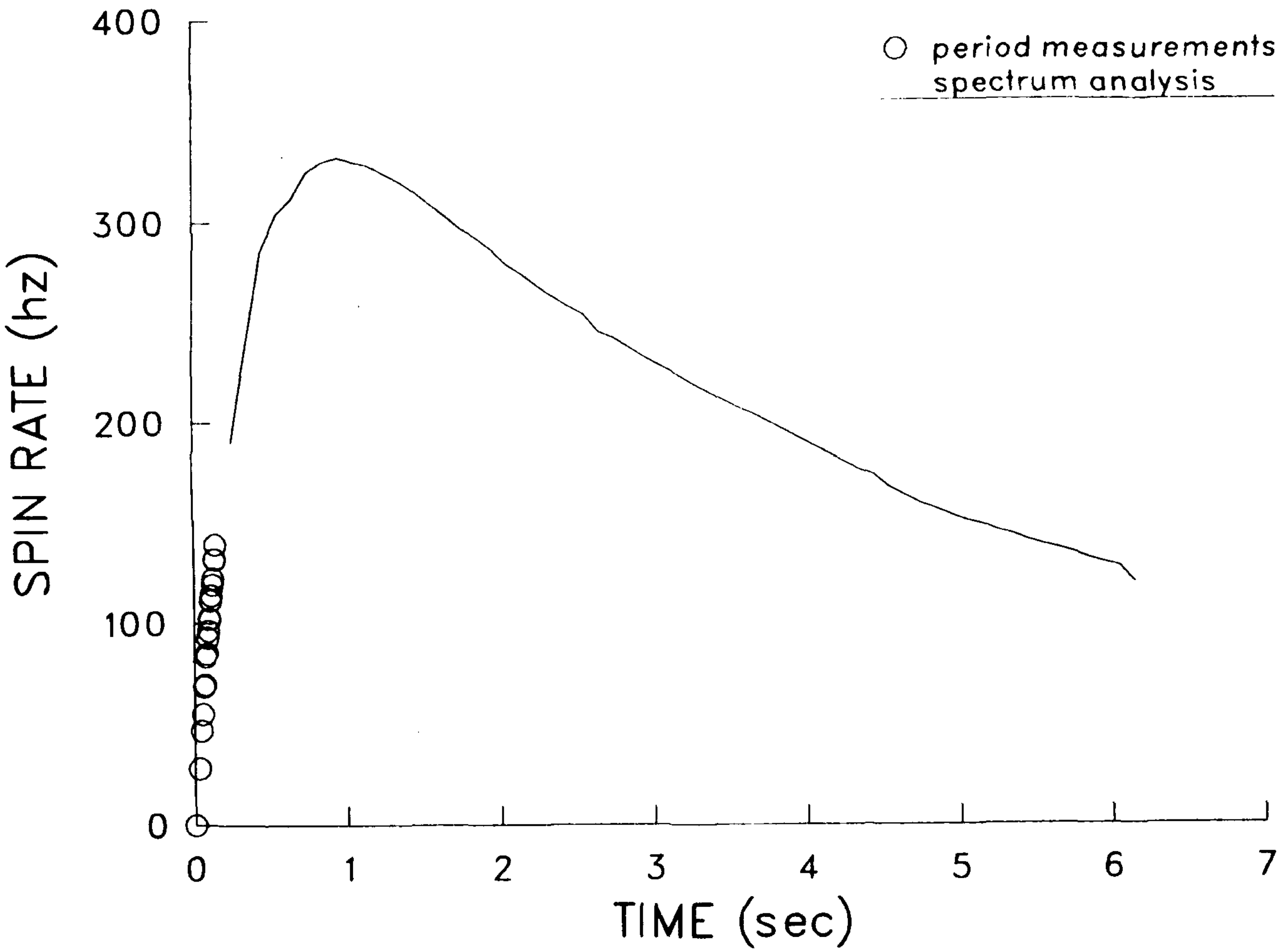


FIGURE 6. Spin Rate Measurements for Round 2.

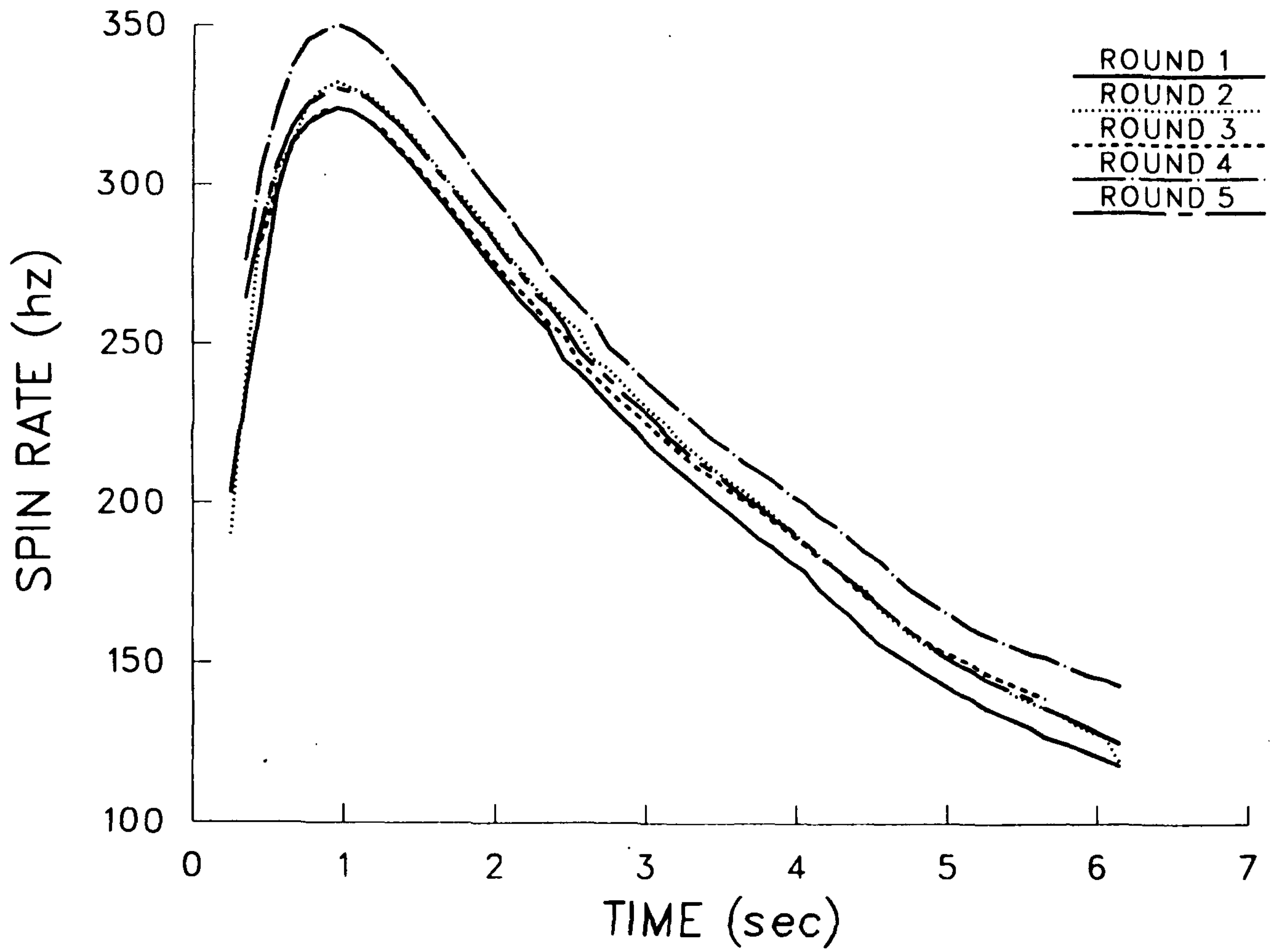
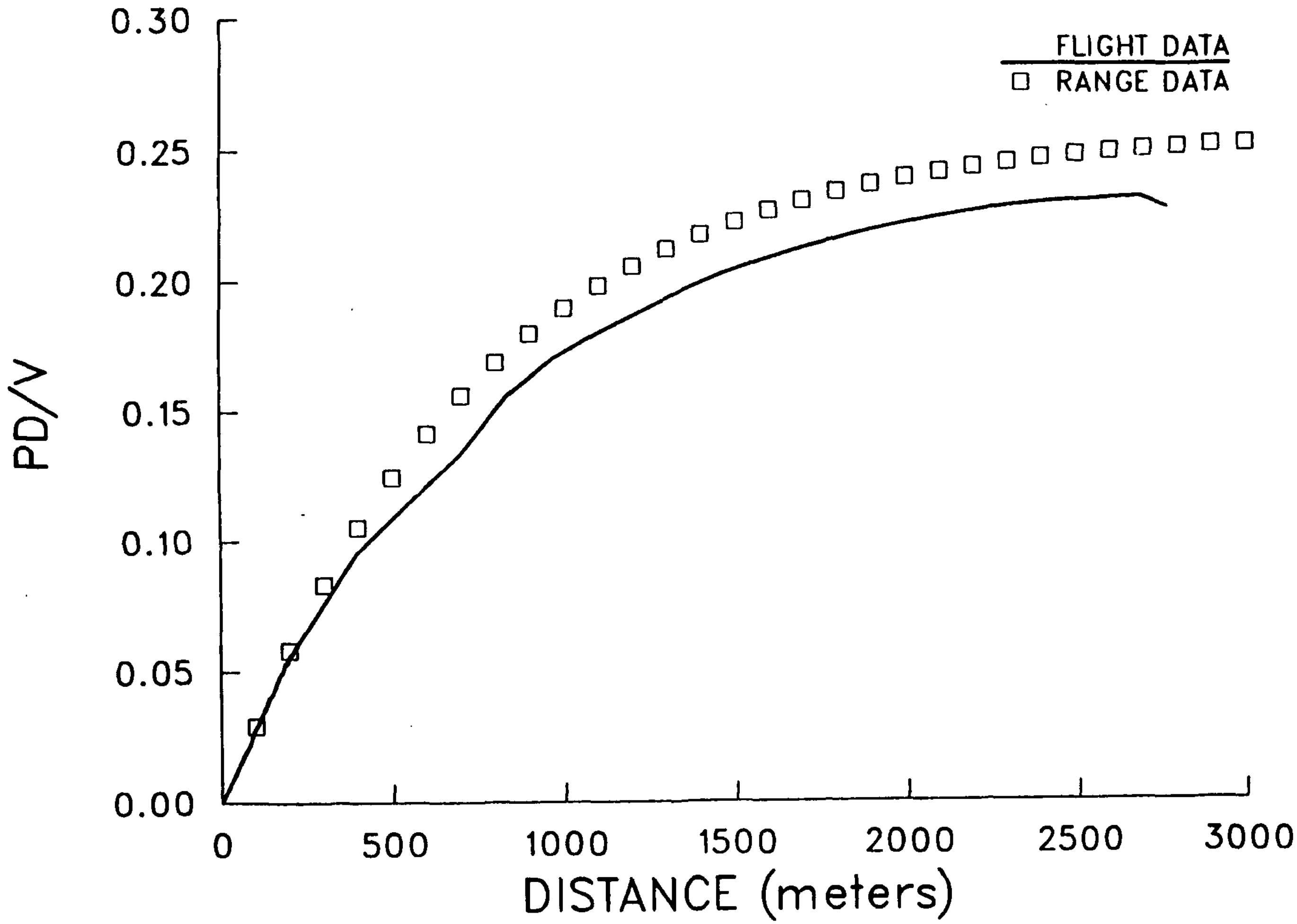


FIGURE 7. Spin Rate Measurements for All Five Rounds.



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